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Cloudiness and cloud genera variability at the turn of the 21st century in Poznań (Poland)

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Abstract— The aim of this article was to investigate the effect of macroscale circulation types on total cloud cover in Poznań-Ławica (western Poland) in years 1951–2015. The analysis was preceded by the characteristics of the long-term, annual, and seasonal changes in total cloud cover and cloud genera (data regarding observations of cloud genera covered the period of 1971–2015). The effect of six macroscale circulation types (Arctic oscillation, North Atlantic Oscillation, East Atlantic, East Atlantic/West Russian, Scandinavian, and Polar/Eurasian Types) on the total cloud cover was examined. The amount of cloud cover in Poznań was influenced by the macroscale circulation types, mainly in the warm part of the year. The North Atlantic Oscillation, Arctic Oscillation and Scandinavian types had the strongest impact there.

Key-word: cloudiness, cloud genera, macroscale circulation, Poznań, Poland

1. Introduction

Clouds affect the environment in many ways, playing a significant role in the transfer of heat and water vapor towards the earth's surface and precipitation reaching the surface of the earth. In addition, they are the main factor influencing the earth's climate system through their share in the radiation balance, by modulating the solar radiation inflow to the earth's surface, and by absorbing long-wave radiation (*Ramanathan et al*., 1989, *Boucher et al.,* 2013). Cloudiness, its size and type depend on many meteorological elements, and its diversity is a factor that also determines climate change (IPCC, 2007). It is currently not possible to ascertain whether recent multidecadal variations in clouds have mitigated or exacerbated anthropogenic global warming (*Norris*, 2008). Cloudiness is the most important meteorological element that reflects the state of the atmosphere, and it is largely shaped by its circulation (*Niedźwiedź* and *Ustrnul*, 1989). The local conditions play great role in spatial differentiation, especially in case of convective clouds and low-level layered clouds (*Okołowicz*, 1962; *Warakomski*, 1962, 1969).

For many decades, it has been the subject of observation allowing researchers to study long-term changes in cloud cover, in particular in connection with atmospheric circulation and synoptic conditions. The influence of clouds on the radiation balance of the planet is measured as the difference between the downward radiation streaming with clouds and without clouds, called radiative forcing (*Ramanathan et al.,* 1989; *Mace et al*., 2006; *Zelinka* and *Hartmann*, 2010). Individual elements of the climate affect the clouds by favoring the conditions that determine the types of clouds and their vertical and horizontal distribution, their composition, and radiation and hydrological properties. Studies of temperature and cloud cover indicate a strong relationship of a temperature increase in Europe with a decrease in cloudiness (*Tang* and *Leng*, 2012). Cloudiness is an element introducing uncertainty to the construction of climate models – the final effect of changes in the cloud amount and structure on the climate system is still unclear, which causes errors in estimating and forecasting the cloud amount in a given area (*Bartok* and *Imecs,* 2012).

The research on cloudiness in various spatial and temporal scales is, therefore, of great importance for understanding climate processes on a global scale. Examining cloud types as well as total cloud cover is essential, because it is a better measure of processes and radiative impacts (*Norris*, 2000). The study aim is the characteristics of the long-term, annual, and seasonal changes in total cloud cover and cloud types in the period 1951–2015. The objective of this study is to investigate the effect of macro-scale circulation patterns on total cloud cover in Poznań (western Poland).

2. *Data and methods*

The analysis was based on the values of total cloud cover and cloud amount at the Poznań-Ławica meteorological station located in western Poland (52°12'N, 18°40'E; 86 m above sea level). Data, verified in terms of quality and homogeneity, came from the database of the Institute of Meteorology and Water Management – National Research Institute (IMGW-PIB). According to *Hahn et al.* (1995), the diurnal cycle in surface-based climatologies can be biased, because visual cloud observations by human observers are less accurate at night. Therefore, observations of cloud cover made three times a day: at 6:00, 12:00, and 18:00 UTC in the period of 1951–2015 were considered for the purpose of the study. The total cloud cover was recorded during the period under consideration at various scales in Poland (at a 0–10 scale during the period 1951–1965 and at a 0–8 scale during the period 1966–2015). Thus, all the values were converted into percents so that the data could be compared. Data regarding observations of cloud genera covered the period of 1971–2015. Ten basic types of clouds were considered in accordance with the International Cloud Atlas (WMO, 1975): *Cirrus (Ci), Cirrocumulus (Cc), Cirrostratus (Cs), Altocumulus (Ac), Altostratus (As), Stratocumulus (Sc), Stratus (St), Nimbostratus (Ns), Cumulus (Cu),* and *Cumulonimbus (Cb)*. The frequency of the occurrence of cloud genera was used to describe the cloud structure. For the total cloud cover, the mean and the 1st and 3rd quartile were calculated on an annual, seasonal and monthly bases. The percentage share of the occurrence frequency of particular types of clouds in observation terms as well as their annual and daily changes were presented. The long-term changes in the occurrence of cloud genera with the trend of changes were determined and the significance of the trend was estimated using the Mann-Kendall test.

In the next step, the effect of macroscale circulation types on the total cloud cover was examined. For this purpose, the correlation coefficient was calculated between the average monthly cloud cover value and the index value of each type of circulation. Monthly indices of six patterns of circulation: Arctic Oscillation (AO), North Atlantic Oscillation (NAO), East Atlantic (EA), Scandinavian (SCAND), Polar/Euroasian (POLAR-E), and East Atlantic/West Russian (EA WR), relevant for Central Europe, were obtained from the databases of the Climate Prediction Center (CPC) of NOAA (1951–2015). The types of circulation specified in the CPC database were determined by means of the principal components analysis based on the monthly values of 500 hPa isobaric surface anomalies (*Barnston* and *Livezey*, 1987).

The positive phase of the Arctic Oscillation (AO) is associated with lower than normal pressure in the Arctic region and with a higher one at moderate latitudes. It causes the blockade of the Arctic air masses inflow to lower latitudes. The negative phase of the AO is associated with higher than average pressure in the Arctic, and with a lower one in moderate latitudes. This pressure pattern is slowing down and shifting the air stream to the south, which promotes the advection of the Arctic air masses to the south (*Higgins et al.*, 2002; *Kang et al.,* 2014). The North Atlantic Oscillation (NAO) is a regional indication of the Arctic Oscillation with centers in the region of Iceland and the Azores Islands. The positive phase of the NAO is associated with negative pressure anomalies in the area of the Icelandic Low and with positive anomalies in the Azores High. As a result, there is a high pressure gradient over the North Atlantic, which causes the intensive advection of humid and warm air masses from the west and the southwest over the northern, western, and central part of parts of Europe. The negative phase of the NAO is related to the opposite distribution of the pressure anomalies. Under these conditions the western flow is slowed down, and there is an inflow of dry and cool air masses from the northeast (*Hurrell*, 1995; *Hurrell* and *Deser,* 2010). Shifted to the southeast towards the NAO is the East Atlantic (EA) type of circulation. Its southern center is associated with the intertropical circulation (*Barnston* and *Livezey*, 1987). The positive phase of the EA is connected with a deep system of low pressure over the Atlantic, causing the advection of warm air masses over Europe. In the negative phase, there is a high pressure system formed over the Atlantic that brings cool and dry air masses (*Josey et al*., 2011; *Mikhailova* and *Yurovsky*, 2016). The Scandinavian circulation type (SCAND) is characterized by the presence of a strong high occurring in the positive phase over the Scandinavian Peninsula with its center over Finland, while the area of lower pressure extends from Western Europe to Eastern Russia and Western Mongolia. The positive SCAND phase is associated with a blocking situation with higher pressure over Scandinavia and Western Russia, while the negative phase is associated with lower pressure than the average over Northern Europe (*Bueh* and *Nakamura*, 2007; *Liu et al.,* 2014). Lower impact on the weather in Europe is shown by the Polar/Euroasian pattern (POLAR-E), which has one main center over the polar region and separate centers of the opposite sign over Europe and northeastern part of China. This system, according to CPC, has its influence in all seasons of the year at 700 hPa (*Gao et al.*, 2016). The positive phase of this system manifests itself in the negative values of the anomalies over the polar region (intensification of the polar vortex), which results, inter alia, in relatively high precipitation in Scandinavia, and the negative phase is associated with the weakening of the polar vortex (*Lorenzo* and *Taboada*, 2005). The least-affecting type of circulation in connection to weather in Central Europe is the Eastern European (EA WR) type characterized by two centers located latitudinally. In the positive phase, the low pressure area is located over the Caspian Sea, while the high is located over Western Europe and the British Isles. In the positive phase, such a system causes the advection of air masses from the northern sector, while the reverse system in the negative phase promotes advection from the southern sector (*Krichak* and *Alpert*, 2005; *Ionita et al.*, 2015; *Lim*, 2015).

3. Results

3.1. Total cloud cover

The average annual total cloud cover from the period of 1951–2015 in Poznań was 64% (*Table 1*). The highest annual total cloud cover was observed in 2013 (72%), and the lowest in 1982 (53%). The standard deviation was 3.5%, which indicates low year-to-year variation in the research period. Winter was the season of the year characterized by the highest cloud amount in Poznań. The average cloud cover was 74%, and the standard deviation was the lowest (5.0%). The highest average cloud amount in winter was observed in 2013 (86%), and the lowest in 1972 (64%). The sunniest season was summer, with the mean total cloud cover of 58% and the highest year-to-year variability (standard deviation 5.6%). The lowest cloud amount in summer occurred in 1983 (43%), and the highest in 2013 (69%). The most overcast month in Poznań was December (77%), and the least was August (55%). The highest average monthly cloud cover was observed in December 1959 (93%). The lowest cloud amount occurred in April 2009 (26%).

Table 1. Mean monthly, seasonal, and annual total cloud cover (%) in Poznań in the period 1951–2015

MONTH	**MEAN**	Q_1	Q_3	**MAXIMUM**		**MINIMUM**	
				VALUE	**DATE**	**VALUE**	**DATE**
I	74	66	79	91	2013	56	1993
II	71	64	77	93	2013	51	1982; 1986
III	63	58	71	79	1981;1985	41	1953
IV	59	54	65	83	1956	26	2009
V	57	50	63	79	2010	38	1989
VI	59	53	65	75	2012	39	1992
VII	58	53	65	82	2000	33	1994
VIII	55	48	60	71	2006	35	1973
IX	56	48	63	79	1978	33	2006
X	62	54	68	81	1974	28	1951
XI	75	71	80	88	1958	55	1984
XII	77	71	82	93	1959	46	1972
YEAR	64	61	66	72	2013	53	1982
Spring	60	69	78	76	2013	45	1953
Summer	57	57	64	69	2013	43	1983
Autumn	64	53	60	77	1952	51	1952; 2005
Winter	74	59	68	86	2013	64	1972

Explanations: Q_1 – 1st quartile, Q_3 – 3rd quartile

The long-term changes showed significant fluctuations in the cloud amount in the subsequent years (*Fig. 1*); however, the decrease in cloud cover in the examined period in Poznań was small (-0.1%/10 years) and statistically insignificant. The deviations of the average annual cloudiness value from the average in the years 1951–2015 reached 11% (*Fig. 2*). In the first part of the research period, the cloud amount showed very considerable year-to-year fluctuations. At the end of the 1970s, significant positive deviations were noted. From 1982 until 1996, there was a period of reduced cloud cover. Next, there were short periods of increase and decrease, and since 2006 one could notice an increase in cloud cover.

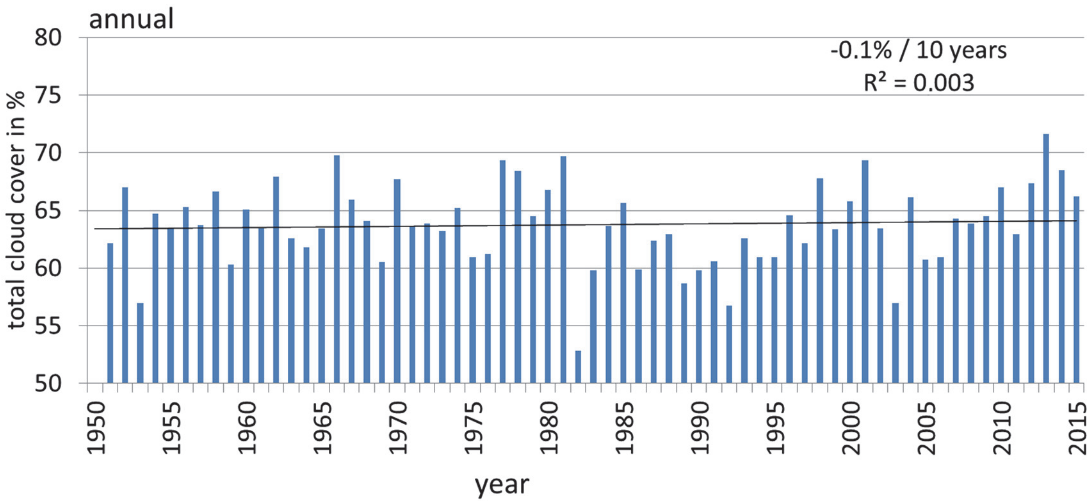

Fig. 1. The long-term course of mean annual cloud cover in Poznań with linear trend and the coefficient of determination R^2 (1951–2015).

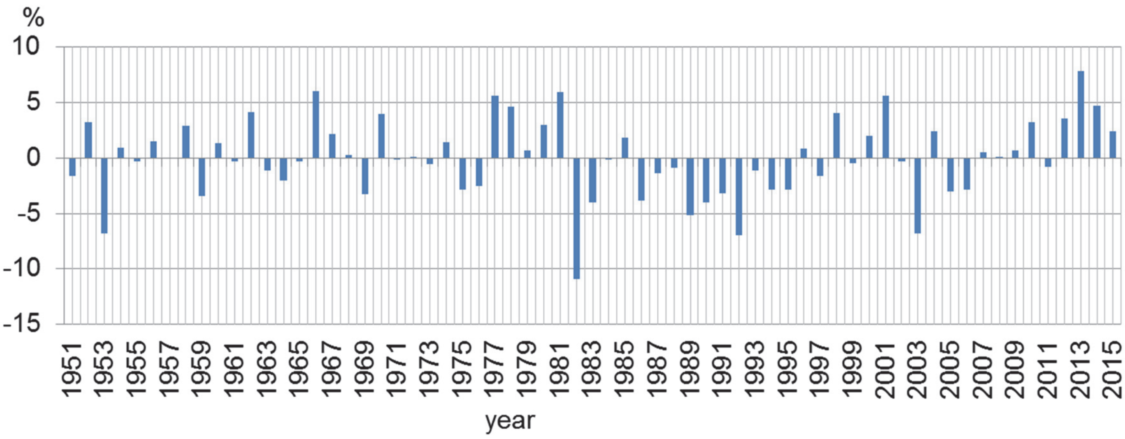

Fig. 2. Deviation of annual cloud cover in Poznań from the average of the period 1951–2015

The largest variations in cloud cover occurred in spring - the amplitude in the whole research period exceeded 30% (*Fig. 3*). The largest difference from year to year occurred in 2009 and 2010 (19.8%) and in 1958 and 1959 (18.8%). The lowest amplitude of cloud cover (aaproximately 21%) occurred in the studied period in winter. The maximum increase in cloud cover was observed in 1951 and 1952, and decrease in 1952 and 1953 (24.1% each). The amplitude of fluctuations in summer and autumn was approx. 28%. In the colder part of the year, a greater increase in cloud cover could be observed in the period of 1951–2015, however, it was not statistically significant.

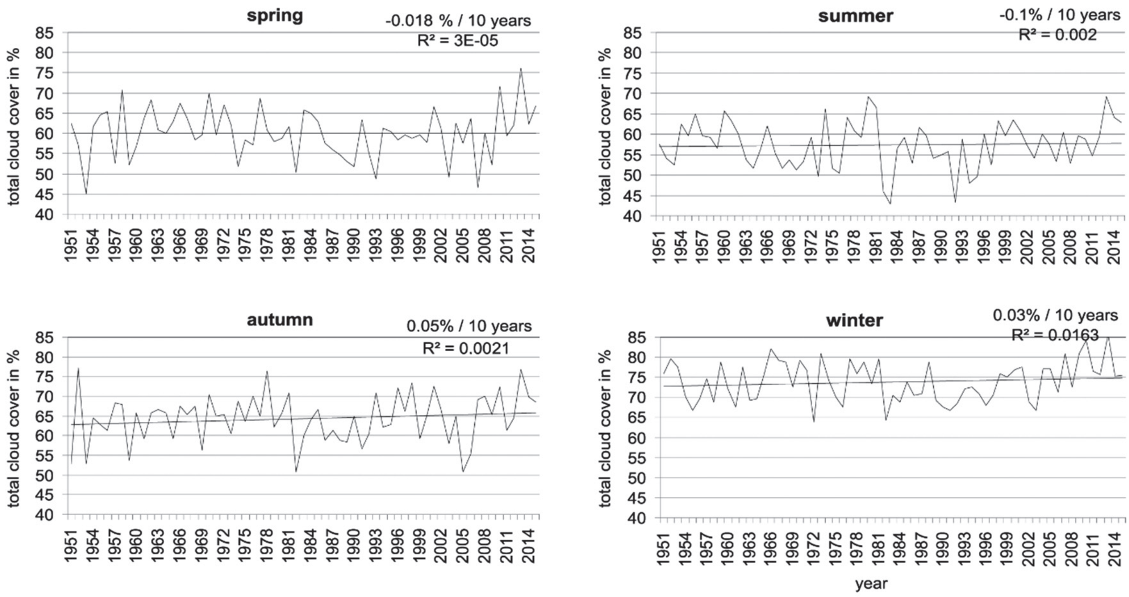

Fig. 3. The long-term course of mean seasonal cloud cover in Poznań with linear trend and the coefficient of determination R^2 (1951–2015).

3.2. *Occurrence of cloud genera*

The most common clouds in Poznań are *Stratocumulus* (25.6%), and the fewest are *Cirrocumulus* (*Table 2*). Next are: *Altocumulus* (18.7%), *Cirrus* (18.5%), and *Cumulus* (14.0%). The cloud cover structure changes throughout the year. In winter, *Stratocumulus* clouds had a much larger share than in other seasons. *Stratus* clouds were also more common then. The frequency of *Cirrus*, *Cumulus*, and *Cumulonimbus* clouds increased in spring and summer. Clouds that did not show significant variation in their frequency during the year are: *Cirrocumulus*, *Cirrostratus*, *Altostratus,* and *Nimbostratus*.

Table 2. Annual and seasonal frequency of occurrence (%) of cloud genera in Poznań (1971–2015)

Months	Cloud genera									
	Ci	*Cc*	*Cs*	*Ac*	*As*	*Ns*	*Sc*	*St*	*Cu*	*Cb*
Year	18.4	0.8	1.3	18.7	3.7	3.3	25.6	9.8	14.0	4.4
Spring	22.9	0.8	1.7	18.9	3.9	3.3	21.8	5.1	16.0	5.6
Summer	22.5	1.2	1.1	23.9	3.2	2.9	14.2	2.8	21.8	6.4
Autumn	17.2	0.7	1.1	19.8	3.8	3.6	28.9	10.9	11.1	2.9
Winter	11.4	0.3	1.2	12.3	3.9	3.2	37.5	20.5	7.1	2.6

High clouds did not change the frequency of occurrence during the day (*Table 3*). Similarly, *Altostratus* and *Nimbostratus* formed with the same frequency at different times of the day. *Altocumulus* and *Stratus* clouds appeared most often in the morning, and least often in the evening. Distinctive daily changes characterized *Cumulus* clouds, which were the most numerous at noon. *Cumulonimbus* was least often observed in the morning, more often at noon and in the evening.

Table 3. Diurnal frequency of occurrence (%) of cloud genera in Poznań (1971–2015)

Cloud Type	**Hour**		
	6 UTC	**12 UTC**	**18 UTC**
Cirrus	17.8	16.3	17.5
Cirrocumulus	1.0	0.5	0.5
Cirrostratus	1.2	1.4	1.2
Altocumulus	20.3	14.7	18.8
Altostratus	3.7	3.8	3.6
Nimbostratus	3.4	3.2	3.2
Stratocumulus	**28.1**	20.7	**33.1**
Stratus	14.6	8.8	10.6
Cumulus	8.0	**25.3**	6.6
Cumulonimbus	1.9	5.3	4.9

Bold indicates the highest values.

The cloud cover structure in Poznań changed over the period under consideration (*Fig. 4*). Types of clouds that tended to increase their occurrence frequency were *Ci, Ac, Sc,* and *Cu*. Only in the case of *Ac*, these were statistically insignificant changes. Decreasing trend concerning the frequency in the years 1971–2015 was shown by clouds *As, Ns, St,* and *Cb*. On the other hand, the frequency of *Cs* clouds, in the first part of the analyzed period, was decreasing, followed by a period of equal frequency until 2007, and since then *Cs* has been observed increasingly often. *Cc* clouds were characterized by very high year-to-year variability of occurrence.

Changes in the annual frequency of occurrence of particular types of clouds at different times of the day are shown in *Fig. 5*. The annual changes in frequency of *Cirrus* were not considerable during the day. It formed more often in the warm part of the year, and much less frequently in the cold part of the year. It was most often observed in spring and autumn, especially in the evening. It was difficult to determine the annual changes of *Cirrocumulus* clouds due to their low frequency, although it could be seen that they were more often observed in the warm period of the year. In the case of *Cirrostratus* clouds, there was a higher frequency in spring, especially in the morning and at noon.

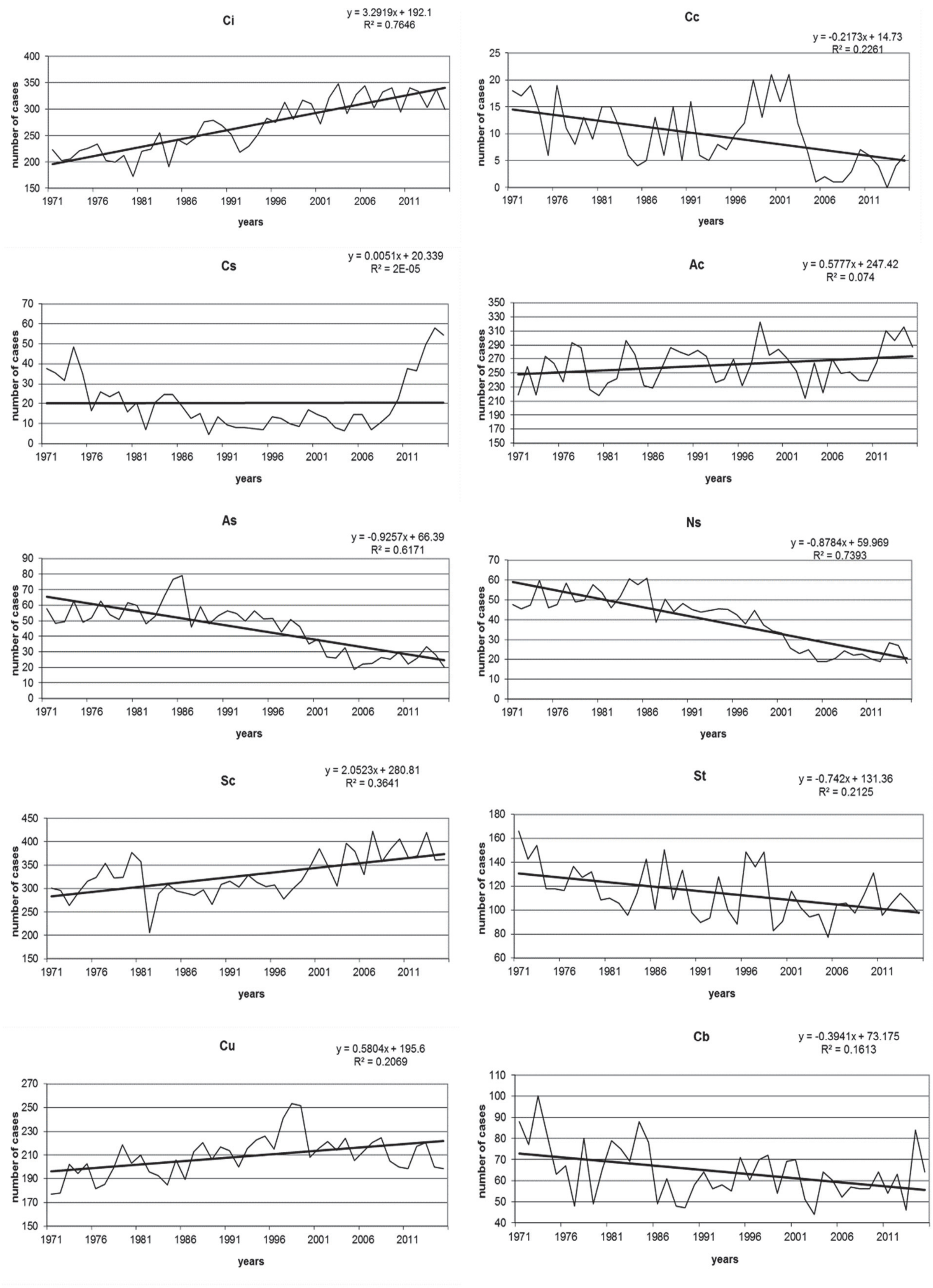

Fig. 4. Multiannual course of the frequency of occurrence of particular types of clouds in Poznań with the trend line and the coefficient of determination R^2 (1971–2015).

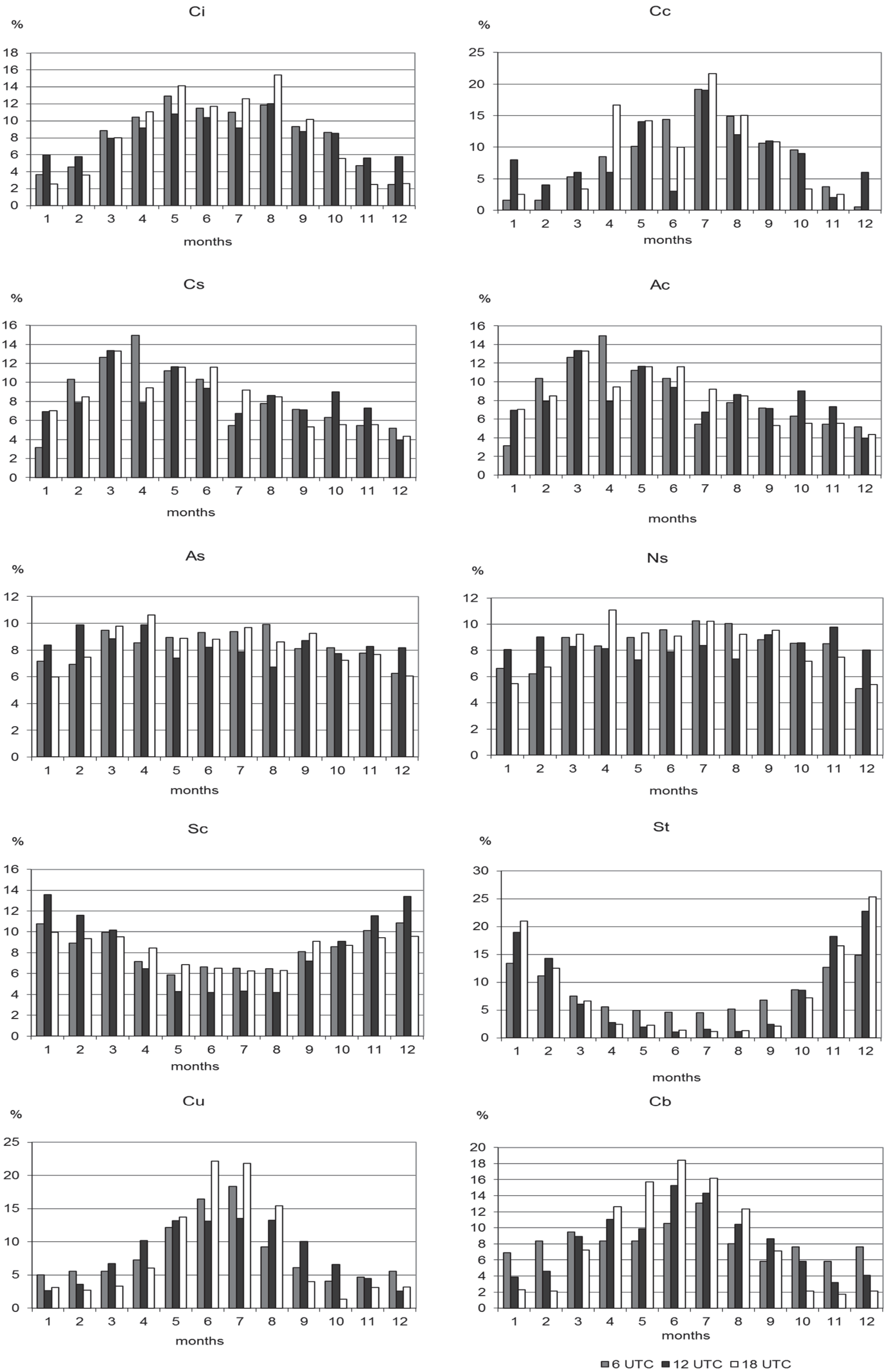

Fig. 5. The annual course of the frequency of occurrence of particular types of clouds in three observation periods in Poznań in the years 1971–2015.

Clear annual changes, varied during the day, with lower frequency in winter and higher in summer, were shown by *Altocumulus* clouds. The highest amplitude of the frequency characterized the evening time; it was slightly lower in the morning, while at noon, the annual course was the most uniform. *Altostratus Nimbostratus* clouds occurred with a similar frequency throughout the year, regardless of the time of day. Annual changes in the frequency of occurrence of *Stratocumulus* clouds was the most diverse at midday - the summer minimum and the winter maximum were clearly marked then. In the morning and evening, *Stratocumulus* also more often appeared in the cold than the warm part of the year, however, the amplitude of the frequency was definitely lower. *Stratus* on the other hand, showed a clear differentiation of the annual changes, especially at noon and in the evening, with the highest frequency in winter and the lowest in summer. The annual changes in towering vertical clouds, *Cumulus* and *Cumulonimbus*, were exactly opposite. They formed much more often in the warm half of the year. *Cumulus* was usually observed the most frequently at noon, and *Cumulonimbus* could be found equally often at midday and in the evening.

3.3. Influence of macroscale circulation types on cloud cover

The Arctic Oscillation (AO) is a type of atmospheric circulation in the Northern Hemisphere, dominating during the winter, in particular. The strongest influence of AO on cloudiness, however, was visible in the warm half of the year (*Table 4*). The correlation in this period was negative and statistically significant. It assumed the highest of values the correlation coefficient in August and September (> -0.4), and slightly lower in June and July.

The North Atlantic Oscillation system, observed throughout a year, was of great importance in shaping the cloud cover in Poznań. The Pearson correlation coefficient was negative and statistically significant from June to October. In December, January, and April the amount of cloudiness did not show any connection with NAO.

The EA pattern had a much smaller impact on the shaping of the cloud cover in Poznań and the correlation coefficient did not exceed -0.3. A somewhat greater influence of EA on cloud cover occurred in June and July.

The Scandinavian pattern was negatively correlated with the amount of cloud cover in Poznań for the most part of the year, which means that a drop in pressure below the average over Northern Europe in the negative SCAND phase caused an increase in cloud cover in the studied area.

The POLAR-E system had a small influence on the amount of cloudiness in Poznań. Only in September, the correlation assumed a statistically significant negative value (-0.5).

The East European pattern did not have a statistically significant impact on the shaping of the cloud cover over Poznań for most of the year. Only in December there was a positive, statistically significant correlation.

Table 4. Coefficients of correlation of the average total cloud cover in Poznań with selected indices of circulation types for the North Atlantic and Eurasia after the Climate Prediction Center (1951–2015)

Index	**Months**											
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
AO	-0.12	-0.26	-0.20	0.09	-0.09	**-0.27**	**-0.18**	**-0.36**	**-0.42**	-0.17	-0.19	-0.17
NAO	0.06	-0.18	-0.14	0.02	-0.15	**-0.38**	**-0.27**	**-0.39**	**-0.29**	**-0.29**	-0.14	0.09
EA	-0.21	-0.19	-0.15	-0.18	-0.20	**-0.27**	**-0.30**	-0.21	-0.12	-0.11	-0.27	-0.18
SCAND	**-0.20**	-0.07	**-0.29**	-0.01	0.01	**-0.29**	**-0.50**	**-0.16**	**-0.36**	**-0.27**	0.18	0.11
POLAR-E	-0.07	-0.09	-0.07	0.03	-0.17	-0.07	-0.01	0.10	**-0.49**	-0.05	-0.14	-0.17
EA WR	-0.05	-0.09	-0.08	-0.01	-0.03	-0.15	0.16	-0.03	-0.14	-0.10	0.07	**0.23**

Explanations: NAO – North Atlantic Oscillation, AO – Arctic Oscillation, EA – East Atlantic, SCAND – Scandinavia, POLAR-E – Polar/Eurasia, EA WR – East Atlantic/West Russia

bold – statistically significant correlation

4. Discussion and summary

On the basis of the conducted research it was found, that the annual values of the total cloud cover in Poznań showed a statistically insignificant downward trend, and among the seasons, its increase was visible in autumn. In Łódź (central Poland), as in Poznań (western Poland), there was a slight decrease in total cloud cover (*Wibig*, 2008). The results of *Wibig* (2008), however, indicated a decrease in the amount of cloud cover in winter and spring in the morning and at noon in Łódź, while a drop in its amount in the evening. In the warm seasons of the year in Poznań, the amount of cloud cover did not change much in the long-term, while in Łódź, in summer, the decrease in the cloud cover was observed (*Wibig*, 2008). In the second half of the twentieth century, in all seasons except autumn, a decrease was found in the amount of cloud cover in Poland (*Żmudzka*, 2003). *Żmudzka* (2007) explained that, probably, an increase in the frequency of lows in this part of Europe, as well as along the North Atlantic - North Sea - Southern Baltic Sea track, areas located to the east of Poland, were the direct cause of the increase in the cloud cover over Poland in autumn. In Lithuania, there was a decrease in low cloud cover in the cold seasons of the year and an increase in the cold seasons in the second half of the 20th century (*Stankûnavičius,* 1998). In the second half of the 20th century, a few percent increases in cloud cover were observed in the area of moderate and high latitudes (*Houghton et al*., 2001). The analysis of *Warren et al*. (2007) on the basis of metadata, showed a slight decrease in total cloud cover in Central and Southern Europe in 1971–1996. The decreasing cloudiness in Europe (apart from Northern Europe) in 1984–2007 was confirmed by *Tang et al.* (2012). The increase in total cloud cover was found in Central Europe (*Henderson-Sellers,* 1986, 1992), Fennoscandian countries and Denmark (*Cappelen*, 2004) as well as in the former USSR (*Sun* and *Groisman*, 2000) and Russia (*Chernokulsky et al.,* 2011, 2013). A similar trend was recorded in Moscow (*Abakumova et al*., 1996) and Estonia (*Keevallik* and *Rusak*, 2001). However, in the area of the Black, Caspian and Aral Sea in the years 1991–2010, no changes in total cloud cover were found (*Calbó et al.*, 2016). The increase in total cloud cover was visible in Spain in the period of 1866–2010, although a decreasing trend was found since the 1960s (*Sanchez-Lorenzo et al*., 2012). The decrease in total cloud cover was observed in other regions, i.e., over the Mediterranean region (*Maugeri et al.,* 2001; *Sanchez-Lorenzo et al.*, 2017). In Kraków (southern Poland), in the period from 1906 to the 40s of the twentieth century, there was an increase in total cloud cover observed; then for two decades it remained at the same level, and since 1961 there was a decrease in cloud cover before the increase from 1983 to 2000 (*Matuszko,* 2003). The spatial variability of long-term changes in cloud cover was found in Poland (*Filipiak* and *Miętus,* 2009) and on the Iberian Peninsula (*Calbó* and *Sanches-Lorenzo,* 2009). *Żmudzka* (2007) stated that the decreasing trends of changes in cloud cover could be explained primarily by the increase in the frequency of anticyclonic patterns over Central Europe. The decrease in the amount of cloud cover in Central Europe as a consequence of the intensification of the activity of highs was indicated also by *Henderson-Sellers* (1986).

Norris (2005), based on the analysis of data from terrestrial and satellite observations, found a relatively small drop in the amount of high clouds, which was not confirmed by the results for Poznań. In Kraków (southern Poland) an increase in the amount of *Ci* clouds was found based on a long series of observations (1906–2000), while *Cs* clouds appeared less and less often (*Matuszko*, 2003; *Matuszko* and *Węglarczyk*, 2018). *Wibig* (2008) found no significant changes in the amount of high clouds in Łódź in the second half of the twentieth century. According to *Eerme* (2004) low average cirrus amounts in spring-summer period were often recorded when the spring was dry, and high cirrus amounts - when it was wet in Estonia. An increase in the amount of cumulus clouds, as in Poznań, in the former USSR was reported by *Sun* and *Groisman* (2000). This confirms as well the previous results obtained by both *Warren et al.* (2007) for Central and Southern Europe, as well as *Sun et al*. (2001) for Eastern Europe. Cumulus clouds that formed more often were also observed in various parts of Poland (*Matuszko* 2003; *Żmudzka* 2007; *Wibig*, 2008). In southern Poland (Kraków) the frequency of occurrence of the *Cu* alone increases in the 1930s, then decreases in the 1950s and again increases (slightly) until 2015 (*Matuszko* and *Węglarczyk,* 2018). As in Poznań, the amount of stratus clouds in the former USSR (*Sun et al.*, 2001) and decreased which was also confirmed by the results of *Matuszko* (2003) and *Matuszko* and *Węglarczyk* (2018) for Kraków in southern

Poland and of *Wibig* (2008) for Łódź in central Poland, as well as by the earlier results of *Warren et al*. (2007). Interannual variations in stratiform cloud amount are related to changes in static stability as explained by *Klein* and *Hartmann* (1993).

Most research on the North Atlantic Oscillation has focused on the winter season. However, studies by *Barnston* and *Livezey* (1987) or *Portis et al.* (2001) showed that NAO is the leading type of teleconnection in all months of the year, including summer. On the other hand, *Wibig* (2008) pointed out that despite the strong influence of NAO on weather conditions in Poland, its impact on the shaping of the cloud cover over Poland was small in all months except April and September. The amount of cloud cover in Poznań was influenced by macroscale circulation types, mainly in the warm part of the year. The North Atlantic Oscillation, Arctic Oscillation, and Scandinavian types had the strongest impact on cloudiness in Poznań. Long-term variability of cloudiness over Europe, and especially of *Nimbostratus* clouds, dependent on NAO, was noticed by *Warren et al.* (2007). *Klein* and *Hartmann* (1993) explain that the amount of stratus clouds appear to be closely tied to aspects of the general circulation of the atmosphere and ocean.

5. Conclusions

In Poznań, in the years 1951–2015, the annual values of the total cloud cover showed a statistically insignificant downward trend, and among the seasons, its increase was visible in autumn. Types of clouds that tended to increase their occurrence frequency were *Ci, Ac, Sc,* and *Cu,* and only in the case of *Ac*, these were statistically insignificant changes. The decrease trend concerning the frequency in the years 1971–2015 was shown by *As, Ns, St,* and *Cb* clouds. On the other hand, the frequency of *Cs* clouds was decreasing in the first part of the analyzed period, followed by a period of equal frequency until 2007, since *Cs* has been observed increasingly often. The amount of cloud cover in Poznań was influenced by macroscale circulation types, mainly in the warm part of the year. The North Atlantic Oscillation, Arctic Oscillation and Scandinavian type had the strongest impact there.

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